22

Cryogens*

Contents

Supplement

* Major chapter revision

22

Cryogens

22.01 Introduction

Cryogens are liquids with boiling points below 200 K (–73°C). Some of their properties and associated hazards are presented below:

- Cryogen burns to the skin can result from direct contact with either a cryogen or uninsulated piping or equipment containing a cryogen.
- Very cold temperatures can cause some materials that come in contact with the liquids to become brittle and lose their mechanical strength.
- High pressures (2–7 MPa) can cause a confining vessel to rupture or even explode if the enclosed cryogen is heated above its critical temperature.
- Cryogens have large liquid-to-gas expansion ratios (generally greater than 700 for most cryogens). A small liquid spill produces a large volume of gas that can displace the air in a confined space, thus creating a serious oxygen deficiency that can suffocate occupants of the area.
- Many cryogens are chemically very reactive (e.g., F_2 and O_2), and others are flammable (e.g., H_2 and CH_4).

Some physical properties of cryogens used at LLNL are shown in Table 22-1. Because of their inherent dangers, cryogenic-fluid systems must be designed, installed, and used in a manner that takes each of these hazards into consideration.

22.02 Responsibilities

Supervisors of personnel handling cryogens are responsible for ensuring their personnel become familiar with the properties and hazards common to all cryogens and with those hazards specific to the cryogens they will be handling. Supervisors shall, as appropriate, train their personnel in safe operating techniques, emergency procedures, and the use of protective equipment, including respiratory protective devices.

All persons working with cryogens are responsible for familiarizing themselves with the properties of cryogens and observing safe handling practices. Individuals unfamiliar with cryogens must work with an experienced person until they gain knowledge and experience.

Responsible personnel shall conduct frequent safety reviews to ensure that no hazardous condition is overlooked and that a safe environment is maintained.

Table 22-1 . Physical properties of some cryogens.

	Cryogen								
Properties	**Ar**	**F_2**	**He**	**H_2**	**Ne**	**N_2**	**O_2**	**CH_4**	**CO_2**
Boiling point (1 atm), K	87.3	85.2	4.2	20.3	27.1	77.3	90.2	111.7	194.7
Critical temperature, K	150.9	144.4	5.2	33.0	44.4	126.3	154.8	190.7	304.2
Critical pressure, MPa (psig)	4.89 (710)	5.57 (809)	0.23 (34)	1.30 (188)	2.65 (385)	3.39 (492)	5.08 (736)	4.64 (673)	7.37 (1070)
Liquid density, g/l	1402	1505	125	71	1206	808	1410	425	1560
Gas density (300 K), g/l	1.63	1.56	0.16	0.082	0.82	1.14	1.3	0.72	2.0
Liquid-to-gas expansion ratio	860	965	780	865	1470	710	875	650	790
Flammable	No	No	No	Yes	No	No	No[a]	Yes	No

[a] **Oxygen does not burn, but will support combustion. Oxygen-enriched atmospheres may lead to violent reactions such as rapid combustion or explosions with incompatible materials.**

22.03 Cryogenic Emergencies

Immediate Treatment for Frostbite

Report to Health Services for medical attention *promptly*. If an emergency occurs during off hours or when definitive medical care is not readily available, the following emergency measures are recommended:

- Warm the affected area *rapidly* by immersion in water not to exceed 105°F; with body heat; or by exposure to warm air. Safety showers with warm water should be provided where there is a sufficient probability of such an accident occurring. In the event of massive exposure, remove clothing while showering. Do not expose the body to open flame. Maintain the affected area of the victim at normal body warmth until professional help arrives.
- Calm the victim and avoid aggravating the injury. People with frostbitten feet should not walk on them. Do not rub or massage the affected parts of the body.
- Prevent infection—use a mild soap to clean the affected area. Dressing need not be applied if the skin is intact.
- If affected, flush the eyes with warm water for at least 15 min.

Evacuation From Area of Spill

Personnel should immediately evacuate an area

- When an alarm signals an oxygen deficiency or other emergency condition.
- If they believe a cryogen spill has caused significant oxygen depletion.
- If they feel light-headed or nauseous following a cryogen spill.
- Following a spill of any highly toxic or flammable cryogen.

Personnel reentering the area must wear self-contained breathing apparatus (SCBA) until the oxygen content of the atmosphere is at least 19.5 percent and no toxic or flammable mixture is present.

22.04 Safety Reviews and Documentation

Cryogenic systems shall, as appropriate, be subjected to a safety review. All cryogenic systems shall be categorized as a minimum of "low hazard," as defined in Supplement 6.06 (Safety Analysis Guide) of this manual.

A Safety Note is required on all manned-area vessels or systems to be used with cryogenic fluids.

22.05 Design of Cryogenic Systems

LLNL cryogenic systems shall, as appropriate, be designed, manufactured or supplied, and installed in accordance with the design criteria outlined in the LLNL Mechanical Engineering Department's *Design Safety Standards*, Section 5.5 (Cryogenic Systems).

22.06 Training and Personal Protective Equipment

Training

An orientation to cryogenic safety is provided as part of course HS-503, "Pressure Safety Orientation" (3 hr). This course is recommended for all users of cryogens.

Personal Protective Equipment

General guidelines for the selection of personal protective equipment are listed in Table 22-2. The Industrial Safety Group of Hazards Control should be consulted for selection of the proper equipment.

22.07 Safe Handling Guidelines

See *Health & Safety Manual*, Supplement 22.01 (Safe Handling of Cryogens).

22.08 References

1. DOE Order 5481.1B (Safety Analysis and Review System).
2. DOE Order 6430.1A, Section 1574 (Cryogenic Systems).
3. LLNL's *Health & Safety Manual*:
   - Chapter 6 (Design and Construction).
   - Supplement 6.06 (Safety Analysis Guide).
   - Supplement 22.01 (Safe Handling of Cryogens).
   - Supplement 32.03 (Pressure Vessel and System Design).
4. LLNL Mechanical Engineering Department's *Design Safety Standards*, Section 5.5 (Cryogenic Systems).

Table 22-2. General guidelines for selection of personal protective equipment.

Hands	**—**	**Loose, nonasbestos, insulating gloves that can be tossed off readily are recommended. Special gloves made for cryogenic work are also recommended. Leather gloves without gauntlet that can be tossed off readily may also be used.**
Eyes	**—**	**Safety glasses** *with side shields* **are required at all times when cryogenic fluids are present. Goggles provide the best protection for the eyes.**
Face	**—**	**Full-face shields shall be used when cryogen is poured, if fluid in an open container is likely to bubble, or when valves are actuated on piping systems, etc.**
Feet	**—**	**Closed-toe shoes that cover the top of the foot are recommended. Cryogenic handlers should wear boots with their trousers extending over the boot.**
Body	**—**	**Long-sleeved clothing made of nonabsorbent material is recommended. Trousers should be cuffless and worn outside boots or over high-top shoes. A leather or other nonasbestos apron should be worn when handling large quantities of cryogens. Full-protective suits should be worn where exposure to drenching is possible.**
Respiratory	**—**	**Supplied air should be used where drenching is possible and where oxygen deficiency or asphyxiation may occur. These types of exposures should be prevented through the implementation of engineering controls.**
Hearing	**—**	**Ear plugs or ear muffs should be used where excessive noise levels may be present. High noise levels may occur near filling and venting operations.**
Tools	**—**	**Tongs or other tools should be used to lift objects out of the liquid or liquid baths.**